A Proposed Change to ITU-R Recommendation 681

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Introduction

Rec. 681 of the ITU-R [1] provides five models for the prediction of propagation effects on land mobile satellite links which are listed below:

1. Empirical Roadside Shadowing (ERS)
2. Attenuation Frequency Scaling
3. Fade Duration Distribution
4. Non-Fade Duration Distribution
5. Fading due to Multipath

Because the above prediction models have been empirically derived using a limited amount of data, these schemes work only for restricted ranges of link parameters. With the first two models, for example, the frequency and the elevation angle parameters are restricted to 0.8 to 2.7 GHz and 20 to 60 degrees, respectively. Recently measured data have enabled us to enhance the range of the first two schemes. Moreover, for convenience, they have been combined into a single scheme named the Extended Empirical Roadside Shadowing (EERS) model.

The Extended Roadside Shadowing Model.

The EERS model estimates the effect of roadside tree shadowing on land mobile satellite links [2]. The inputs to this model are link frequency, elevation angle, and the percentage of link outage. The output is the fade depth experienced at the given percentage, or stated differently, the required margin for the given percentage of link outage. The ranges of frequency f (GHz), elevation angle), θ (degrees), and percentage, p, are

$$0.8 \leq f \leq 20$$
$$7 \leq \theta \leq 60$$
$$1 \leq p \leq 80$$

The EERS is an empirical model based on cumulative fade distribution measurements at UHF (870 MHz), L-band (1.6 GHz) and Ka-band (20 GHz). The population density of trees along the roadside is represented by the percentage of optical shadowing caused by roadside trees at a path elevation angle of 45 degrees in the direction of the signal source, that is the satellite. The EERS model is valid for the percentage of optical shadowing ranging from 55 to 75%.

For $1\% \leq p \leq 20\%$, the EERS model can be presented by

$$A(p,\theta,f) = A(p,\theta,f_L)\exp\{1.5(\frac{1}{\sqrt{f_L}} - \frac{1}{\sqrt{f}})\} \tag{1}$$

and for $20\% < p \leq 80\%$ the model is given by

$$A(p,\theta,f) = A(20\%,\theta,f)\frac{\ln(\frac{80}{p})}{\ln(4)} \qquad (2)$$

where $A(p,\theta,f)$ is the attenuation at the frequency f (GHz) exceeded at the percentage of the driving distance p for a path angle, θ, and $A(p,\theta,f_L)$ is the corresponding attenuation at f_L = 1.6 GHz. The attenuation is defined relative to non-shadowed and negligible multipath condition.

For 20< $\theta \leq 60$ deg, the attenuation $A(p,\theta,f_L)$ is given by

$$A(p,\theta,f_L) = \alpha(p) + \beta(p)\theta + \gamma(p)\theta^2$$

and for $7 \leq \theta < 20$ deg,

$$A(p,\theta,f_L) = A(p,20^\circ,f_L)$$

where

A: fade exceeded in dB with respect to unshadowed propagation,
p: percentage of the distance traveled over which the fade is exceeded, and
θ: path elevation angle to the satellite in degrees.

The parameters $\alpha(p)$, $\beta(p)$, and $\gamma(p)$ are tabulated in Table 1.

Table 1. Values of $\alpha(p)$, $\beta(p)$, and $\gamma(p)$ of the EERS Model

Percentage	$\alpha(p)$	$\beta(p)$	$\gamma(p)$
20	24.45	-0.7351	5.991×10^{-3}
10	26.84	-0.6775	4.605×10^{-3}
5	29.22	-0.6000	3.219×10^{-3}
2	32.38	-0.5106	1.386×10^{-3}
1	34.76	-0.4430	0.0

The EERS model corresponds to an average propagation condition with the vehicle driving in lanes on both sides of the highway -- lanes close to and far from roadside trees. The model applies to highway and rural roads where the overall aspect of the propagation path is, for the most part, orthogonal to the line of roadside trees and utility poles, a slightly conservative scenario. It is assumed that the dominant cause of signal attenuation is canopy shadowing (see Recommendation ITU-R PN. 833). Figure 1 shows plots of fade exceeded versus the path elevation angle for several constant percentages, p.

Although the EERS model has been tested only for the frequency rang of 0.8-3 GHz and a single frequency of 20 GHz, it is suggested for use as a straw model for in between frequencies, i.e., 3 to 20 GHz.

Extension of Elevation Angle Upper Bound.

Data from the UK indicate that the elevation angle range of the EERS model for L- and S-band frequencies (1 to 3 GHz) and $p \leq 30\%$ can be extended to 90 degrees. This can be achieved by linear interpolation between the EERS model at 60 deg and the data provided in Table 2 at 80 degrees The value of attenuation at 90 degrees is suggested to approach zero.

Table 2. Fade Exceeded (dB) at 80 deg (measurements in the UK)

Tree-Shadowing; mature deciduous trees of varying density and distance from the road.		
p (%)	1.6 GHz	2.6 GHz
1	4.1	9.0
5	2.0	5.2
10	1.5	3.8
15	1.4	3.2
20	1.3	2.8
30	1.2	2.5

Summary

The extended road side shadowing model is a tool for the prediction of fades on mobile satellite links. EERS is an empirical model based on data obtained on U.S. roads and highways with tree shadowing as the primary source of fading and a small contribution from utility poles, man-made objects, and natural obstacles. This model corresponds to an average propagation condition.

Reference

1. ITU-R Recommendations, 1994 PN Series, Geneva, Switzerland, 1995, pp. 358-365.

2. J. Goldhirsh and W. Vogel, "Extended Empirical Roadside Shadowing Model from ACTS Mobile Measurements," Proceedings of NAPEX XIX, JPL Pub. 95-15, Aug. 1, 1995, pp. 91-102.

FIGURE 1
Fading at 1.5 GHz due to Roadside Shadowing versus
Path Elevation Angle